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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.

RAIN SIMULATOR STUDIES OF THE EFFECT OF SLOPE ON EROSION AND RUN-OFF 1938

A Preliminary Report

Northwest Appalachian Soil and Water
Conservation Experiment Station
Zanesville, Ohio

SCS-TP-36
August 1940

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A Preliminary Report

By

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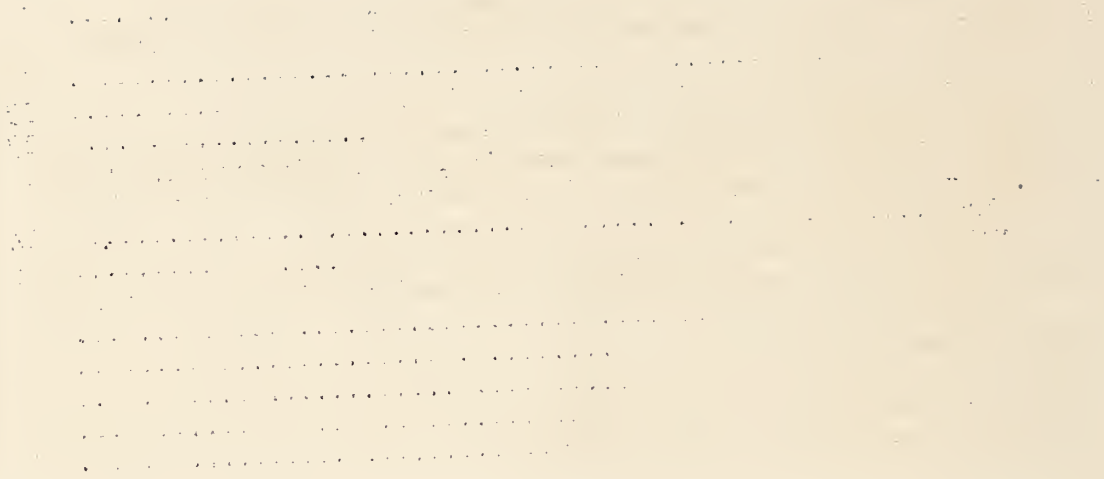

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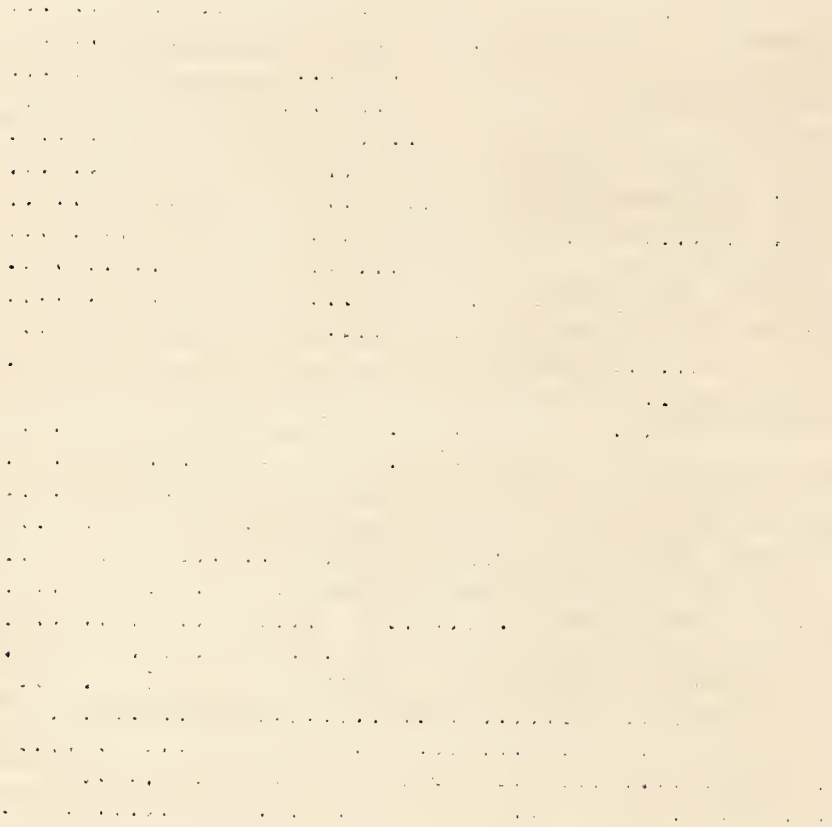

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RAIN SIMULATOR STUDIES OF THE EFFECT OF SLOPE ON EORISON AND RUN-OFF

Introduction

The five principal factors affecting erosion and run-off are soil type, degree of slope, length of slope, amount and intensity of rainfall, and land use. The development of apparatus to apply rain to plots artificially has made it possible to isolate some of these factors for study.

The present study was designed to determine the effect of the degree of slope on erosion and run-off. By means of the artificial rainfall apparatus the amount and intensity of the rain could be held constant; the length of the plot was held constant; and the land use was held constant by having all plots in a uniform fallow condition. The only factor which could not be held constant was the soil type since it was impossible to locate an area of uniform soil covering the wide range of slopes which it was desired to study. This report covers the experimental work which was carried on during the summer of 1938 at the Soil Conservation Experiment Station at Zanesville, Ohio. It is planned to continue and extend this work by adding different kinds and degrees of cover and additional soil types in the near future.

Experimental Procedure

The apparatus.

The apparatus used in these experiments was developed by the Soil Conservation Service at the Hydraulic Laboratory of the National

Bureau of Standards. It is one of a number of such devices developed by personnel of the Hydrologic Division and has been designated by them the "Type E" apparatus to distinguish it from others in the series. A full description of this apparatus will be found in Appendix A.

Performance of the apparatus.

Drop-size and distribution.--Tests made during the development of the Type E apparatus indicate that the drops produced are considerably smaller than those ordinarily occurring in natural rains of the same intensity. For this reason it is probable that infiltration rates determined by this apparatus are somewhat greater than the rates that would occur under natural rainfall. Moreover, less erosion was undoubtedly produced by the spray of the Type E apparatus than would occur under natural rainfall of the same intensity. However, since the primary purpose of this study was a comparison of the run-off and erosion from different degrees of slope, these characteristics of the apparatus are not believed to affect the reliability of the results.

Laboratory trials and further tests after the apparatus was set up at the Station showed a very good distribution of the spray with the exception of a slight fading near the sides of the plot. The rate of water application was fairly constant from run to run. Late in the season, an accurate water meter was obtained for the supply line so that the total amount of water used in the various

runs could be compared as an additional check on intensity of application. The use of the meter offered no guarantee of uniformity of catchment on the plot. It served, however, to guard against gross errors in pumpage. The results of three tests of the apparatus with the meter installed are given below:

Table 1.--Comparison of volume pumped as measured by meter and run-off from sheet metal plot surface.

Run No.	Volume Pumped 8 min.	Volume Pumped 15 min.	Runoff from Sheet Metal Surface	Percentage Plot Catchment to Pumpage
	Cu.Ft.	Cu.Ft.	Cu.Ft.	Pct.
1	32.06	59.74	38.16	63.88
2	31.60	59.28	38.45	64.86
3	31.82	59.82	38.50	64.36
Average Pct. - Plot catchment to pumpage				64.32

In spite of the canvas walls, wind of more than 5 miles per hour affected distribution and intensity. No runs were made on windy days.

Methods of investigation.

The plots.---The plots were one one-hundredth acre in area, 72.6 feet long (horizontal measurement) by 6 feet wide. They varied in slope from 2.9 percent to 22.5 percent. The area on which the plots were located had not been cultivated for at least six years. The vegetation, for some time, had been sparse grass and annual weeds.

Before the plots were laid out, the area was plowed to a depth of 6 inches, disced and harrowed. Metal plot borders were driven 6 inches into this loose soil in installing the plots. The soil was allowed to settle approximately a month before experiments began.

The soils of the plots.---The following description of the soils was abstracted from a detailed survey of the plots made by A. H. Paschall (12). Although the soil on which the study was made was all classified in 1932 as Muskingum silt loam, the gentler sloping ridge tops are now called Wolston silt loam. The more rolling areas and steeper slopes are still called Muskingum.

Plots 8 and 9 (figure 1) on the gentler slopes (2.9 and 4.2 percent) were on the Wellston soil. Considerable (4 to 5 inches) of the original top soil, a grayish-brown silt loam, remains on this area although there has been considerable mixing with the subsoil by tillage operations. The subsoil between the depths of 6 to 20 or 24 inches, is a bright yellowish-brown or buff colored

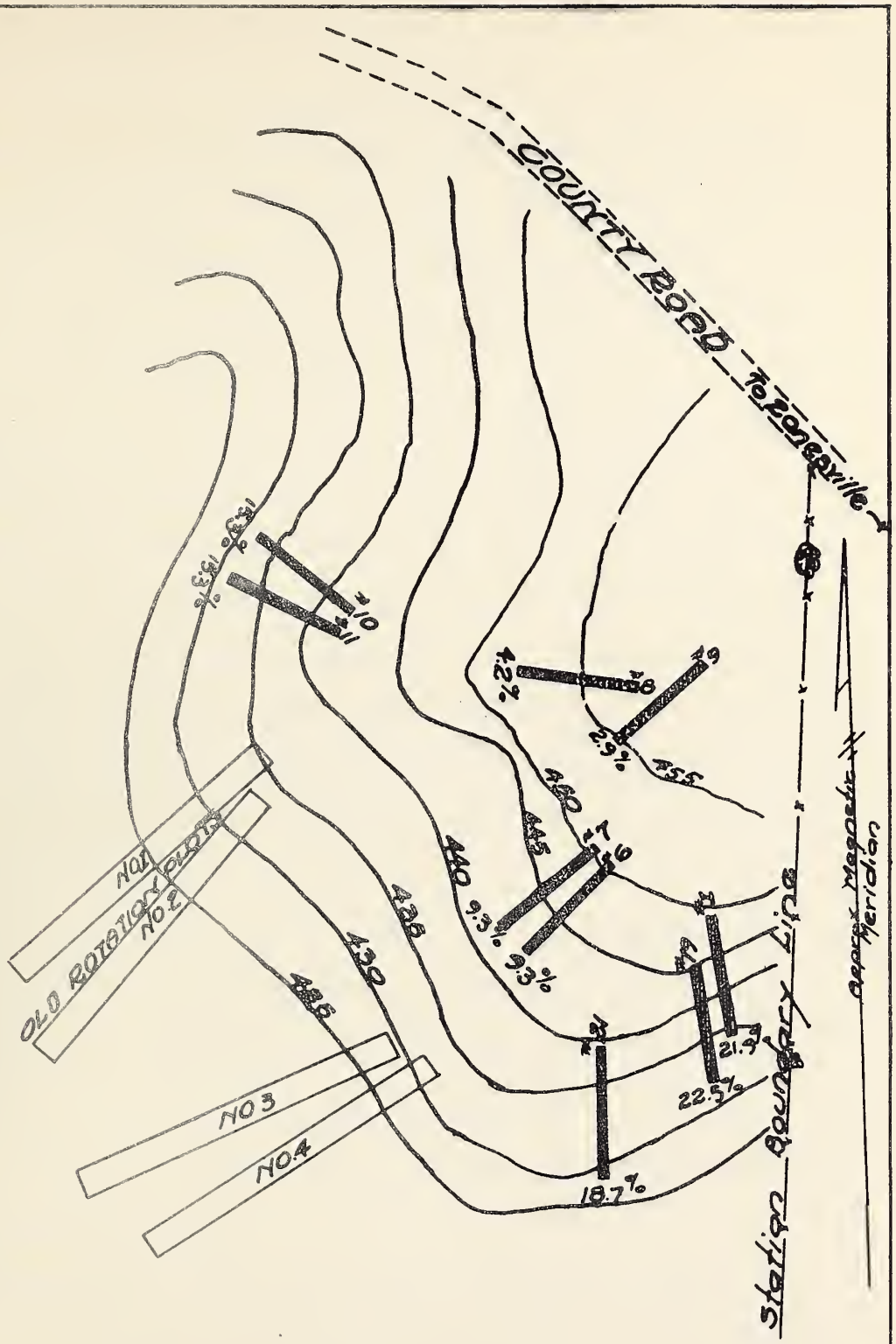

Figure 1.—Plots used in degree of slope studies with the rain simulator. Scale 1" = 100

dense silty clay loam that is slightly plastic when wet but crumbles readily when dry. Beneath this layer, the material, to a depth of 36 to 38 inches, varies from slightly weathered fine grained sandstone to plastic clay. The parent material is sandstone. On the average, internal drainage is good.

Plots 6, 7, 10, and 11, on the 9.3 and 15.3 percent slopes, were typical Muskingum silt loam. More than 50 percent of the original surface soil, a yellowish-brown silt loam, has eroded from these plots and that which remains has been thoroughly mixed with the subsoil to plow depth, by tillage. Below the plow layer and extending to a depth of 10 to 14 inches, is a bright yellowish brown, dense silty clay loam very similar to the Wellston subsoil. Below this horizon occurs slightly weathered micaceous sandy shale of yellow-olive color.

The steeper plots 1, 19 and 21, on the 18 and 22 percent slopes, were on a steep phase Muskingum silt loam. All the top soil has gone so that now the soil, to a depth of 10 to 15 inches, is a mixture of soil material with numerous rock and shale particles. Below this depth is slightly weathered sandstone and sandy shale parent material.

Volume weight samples of the upper and second 6 inches of soil were taken in quadruplicate from each plot before the experiment was started. The determinations are given in table 2.

Table 2.--Field volume weights of the plots

Plot No.	9	8	7 & 6	10	11	21	1	19
Slope %	2.9	4.2	9.3	15.3	15.3	18.7	21.9	22.5
0-6"	1.19	1.27	1.23	1.24	1.23	1.35	1.28	1.21
6-12"	1.45	1.42	1.55	1.65	1.60	1.67	1.63	1.40

It is evident that there was a soil variable in the plots used. It would be difficult to find soils on slopes varying in steepness, as do those studied, which would be similar. Observations and exploratory runs indicated that with the high rate of rainfall used in the study and the short duration of the runs, the subsurface character of the plots was a minor factor and that moisture content and surface preparation overshadowed all other plot characteristics.

Preparation of the plots.--All plots used were uncropped. Before each run, the surface was prepared by a thorough hoeing to a depth of two inches or slightly more. After raking to pulverize all large clods, the soil was then screeded to eliminate surface depressions and to level it across the plot. It was then cross-raked with a rubber-toothed garden rake to eliminate longitudinal marks. The purpose of this preparation was to have a cultivated plot with as near a plane surface as possible, that would distribute the runoff so that cross-flow, storage in small depressions

or concentration in rills would be minimized. The same preparation was used on all plots in order to eliminate, as nearly as possible, the surface variable from plot to plot. Five moisture samples, 0 to 6 inches deep, were taken before and after each run.

The operation of the apparatus.

Since the apparatus delivered water over an area wider than the plot and the distribution of the water was somewhat less toward the borders of the total area covered, it was impossible to ascertain the rate of application by any method of measuring of the total water used. The following method was adopted for measuring the rate of water application.

Over the entire plot surface was placed a sheet metal cover especially planned so that it could be handled in sections. Spray was applied to this surface and the run-off was caught in a tank. From the relationship between the total time rain was applied and the total catchment in the tank, the effective intensity of water application was computed. It was assumed that the subsequent runs on one location were at the same rate as indicated by the "sheet metal" trial.

The apparatus was operated on pump pressure entirely. Water was supplied to the pump from a constant head tank which was supplied by gravity through a valve-controlled two-inch pipe from a battery of interconnected tanks of nearly 2000 gallons, aggregate

capacity. Since the water used was hauled from a creek, care was taken in screening out even the finest debris to avoid clogging of the nozzles.

At the beginning of each run, the deflectors over the nozzles were lowered to keep the water off the plot. The valves in the lower ends of the main supply lines were left open so as to free the lines of air. After they were closed, the valves supplying each nozzle assembly were adjusted so that a pressure of five pounds registered on all gages. At a given signal, the deflectors were raised and the test was begun.

The run-off from the plots was caught by 30-second intervals in separate containers. Corrugated sheet metal cans of 10 gallon capacity were used.

A shallow pit was excavated just below the end of the plot, large enough to accomodate two cans and an attendant. The run-off was directed by the attendant into one container or the other by means of a pivoted flume attached to the "concentrator" at the end of the plot.

The volume of each 30-second run-off increment was determined by means of a point gage and a sample for the determination of soil content was taken by splitting through a cone sampler[1]. The run-off in each container, after the sample was removed, was

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[1]Constructed from plans by Dr. E. P. Deatrick.

poured into a large tank. "End point" soil loss was determined from the soil in this tank plus the soil in the increment samples. The soil content of the samples was determined by the usual flocculation, decanting, drying and weighing procedure.

Timing.— Timing was done by means of a stop watch and an ordinary watch, frequently compared.

At the beginning of a minute as determined by the second hand of the watch, the signal was given to apply water to the plot. (Several previous warning signals had been given so that the attendant on each side of the plot could quickly depress the lever lifting the deflectors.) At the same instant, the stop watch was started. This time marked the beginning of rainfall and rain was continued for 15 minutes. The rain was stopped in a similar manner.

The lower end of the plot was carefully watched and the instant that run-off started was observed on both watches. After 25 seconds a warning signal was given to the attendant in the pit who prepared to change containers. Each second was counted aloud as 5, 4, 3, 2, 1 and at zero a signal of execution was given. After a little practice between timekeeper and pit attendant, it was possible to change containers with less than one-half second total error per increment.

The various runs.--The first run was made with the sheet metal cover over the plot. Although this run was made to measure

the intensity, the run-off was caught at 30-second intervals with the idea that hydrographs from these runs on the different slopes could be compared. The second run was made with a burlap covering over the sheet metal. The purpose of the run on the burlap was to obtain a hydrograph with prolonged rising stage and one unaffected by infiltration. The burlap delayed the run-off and thus prolonged the rising stage of the hydrograph. It also tended to increase surface detention.

The third run (dry run) was made on the bare soil at field moisture content. The fourth run (wet run) followed the third as soon as the measurement and sampling of the run-off from the previous run permitted. All runs were of 15-minute duration.

The following is a tabulation of all the runs except those on sheet metal.

Table 3.--Tabulation of rain simulator run data

Run No.	Plot No.	Slope	Date	Character of Surface
		Pct.		
B-25	10	15.3	8/2/38	Burlap cover sheet metal
25	10	15.3	8/3/38	Cultivated soil - dry run
26	10	15.3	8/3/38	Cultivated soil - wet run
B-27	11	15.3	8/8/38	Burlap covered sheet metal
27	11	15.3	8/9/38	Cultivated soil - dry run
28	11	15.3	8/9/38	Cultivated soil - wet run
B-29	9	2.9	8/12/38	Burlap covered sheet metal
29	9	2.9	8/12/38	Cultivated soil - dry run
30	9	2.9	8/12/38	Cultivated soil - wet run
B-31	7	9.3	8/17/38	Burlap covered sheet metal
31	7	9.3	8/17/38	Cultivated soil - dry run
32	7	9.3	8/17/38	Cultivated soil - wet run
B-33	6	9.3	8/19/38	Burlap covered sheet metal
33	6	9.3	8/19/38	Cultivated soil - dry run
34	6	9.3	8/19/38	Cultivated soil - wet run
B-35	19	22.5	8/23/38	Burlap covered sheet metal
35	19	22.5	8/23/38	Cultivated soil - dry run
36	19	22.5	8/23/38	Cultivated soil - wet run
B-37	1	21.9	8/26/38	Burlap covered sheet metal
37	1	21.9	8/26/38	Cultivated soil - dry run
38	1	21.9	8/26/38	Cultivated soil - wet run
B-39	21	18.7	9/2/38	Burlap covered sheet metal
39	21	18.7	9/2/38	Cultivated soil - dry run
40	21	18.7	9/2/38	Cultivated soil - wet run
B-41	21	18.7	9/28/38	Burlap covered sheet metal
41	21	18.7	9/28/38	Cultivated soil - dry run
42	21	18.7	9/28/38	Cultivated soil - wet run
B-43	9	2.9	10/4/38	Burlap covered sheet metal
43	9	2.9	10/4/38	Cultivated soil - dry run
44	9	2.9	10/4/38	Cultivated soil - wet run
B-52	8	4.2	10/14/38	Burlap covered sheet metal
52	8	4.2	10/14/38	Cultivated soil - dry run
53	8	4.2	10/14/38	Cultivated soil - wet run

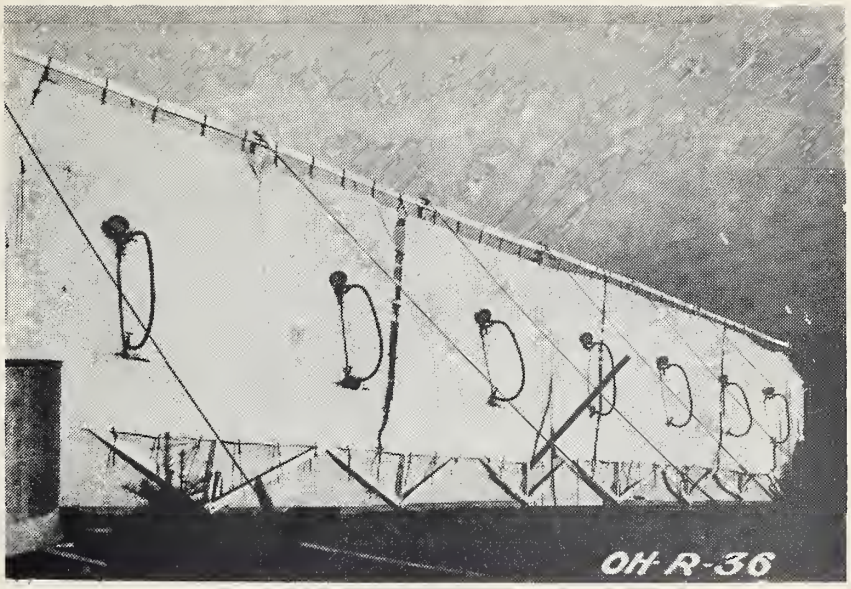

Plate I -- Side view of assembled apparatus on a 13% slope.

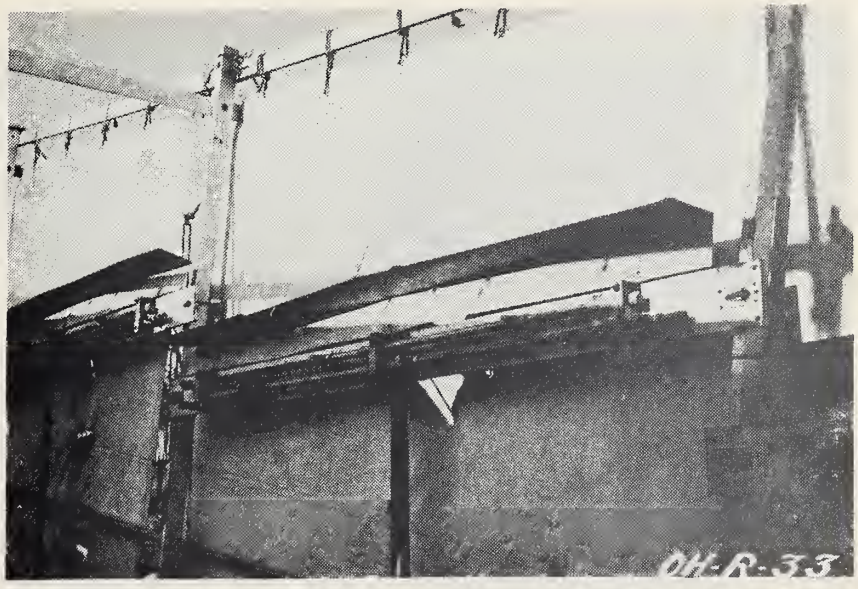

Plate II -- Detail of nozzle-board showing nozzles and one inch mounting pipes. Sheet metal deflector is in operating position.

Plate IV -- Burlap in place on sheet metal cover.

Plate III -- Intensity run on sheet metal just completed. Metal has been squegeed and unscrewed preparatory to removal.

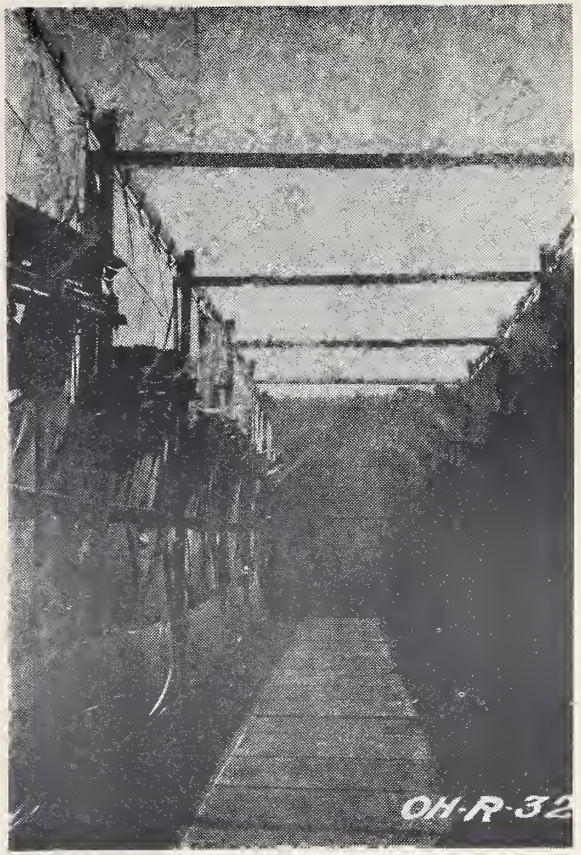

Plate VI -- Nozzles supplying four inches per hour to sheet metal surface.

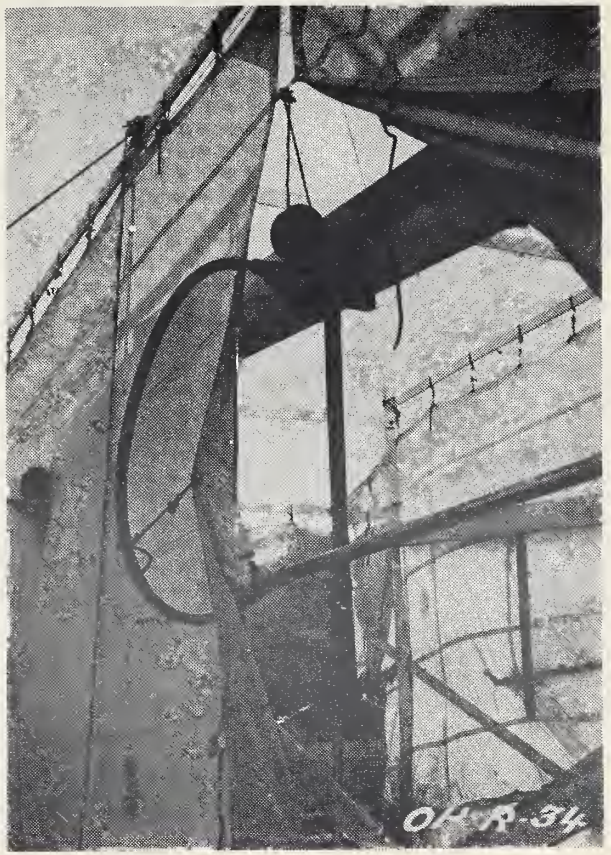

Plate V -- Detail of $1\frac{1}{2}$ inch supply pipe, regulating valve, connecting hose and pressure gage.

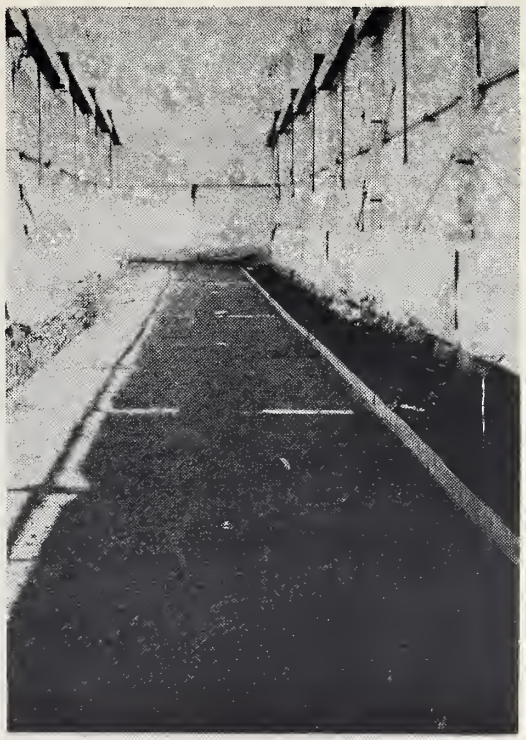

Plate VIII -- Plot on 9% slope with surface cultivation after cross leveling and screeding.

Plate VII -- 9% slope plot after dry run of 1 inch. Much less gullying than usual.

Plate X -- 9% plot after wet run. An unusual type of erosion.

Plate IX -- 22.5% plot before run.

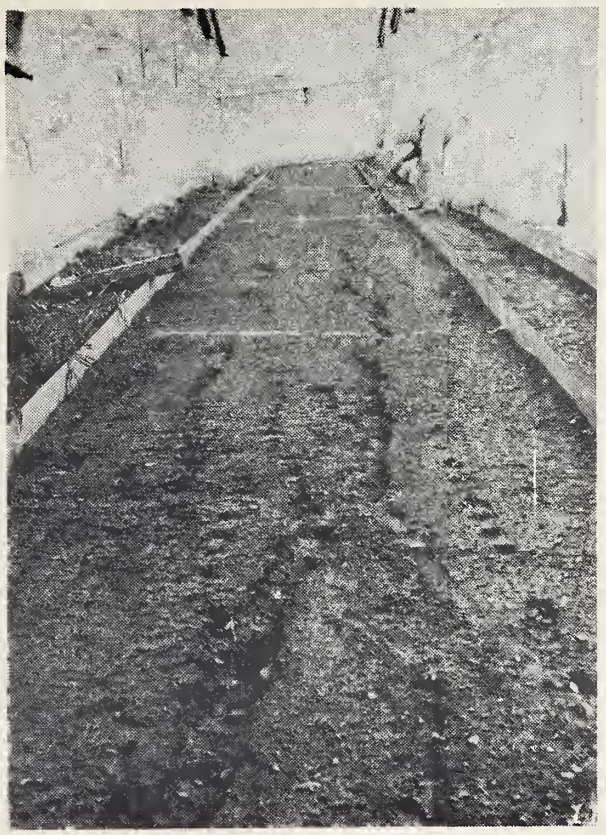

Plate XII -- 21.9% plot after dry run.

Plate XI -- 22.5% plot after wet run. A similar gully pattern developed for most runs on slopes of 9% or more.

Results

Soil and water loss data for the runs are summarized in tables 4 and 5. Sample tables showing the manner in which the original and computed data for all runs was tabulated, are included in Appendix B.

The effect of slope on infiltration.

Total infiltration was computed for all soil runs on the various slopes by subtracting total run-off from total rainfall (see tables 4 and 5). An average infiltration rate for each run was calculated from total infiltration and the time elapsing from beginning of rain application to end of run-off. These values (particularly those of the dry runs) obviously have little significance as a measure of the infiltration rate of the soil profile. They are of interest, however, in a study of the effect of slope on infiltration.

Infiltration rates obtaining during the equilibrium flow period of the wet runs, were computed by subtracting the average rate of run-off (taken from the run-off graph) from the application rate. (The equilibrium flow period was reached when the rate of run-off had become sensibly constant.) These rates, as shown in table 6, vary from 0.42 inch per hour for the 2.9 percent slope

Table 4.—Summary of data from rain simulator - dry soil runs on the various slopes.

Plot No.	Slope	Run No.	Date	Volume Weights		Soil Moisture 0-6 inches	Intensity	Soil Loss per Plot	Water Loss	Density per Cu.ft.	Infiltration	
				0-6 in.	6-12 in.						Total	Average Rate
	Pct.		1938			Pct.	In.per Hr.	Lbs.	Pct.	Lbs.	In.	In.per Hour
9	2.9	29	8/12	1.19	1.45	21.8	4.17	23.9	53.8	1.17	0.48	1.49
9	2.9	43	10/4	1.19	1.45	19.3	3.98	20.4	62.3	0.91	0.39	1.19
	Av.						4.07	22.1	58.0	1.04	0.44	1.34
8	4.2	22	7/25	1.27	1.42	14.2	4.04	34.0	61.1	1.49	0.39	1.28
8	4.2	52	10/14	1.27	1.42	12.9	4.11	22.9	51.6	1.19	0.50	1.62
	Av.						4.08	28.4	56.3	1.34	0.44	1.45
7	9.3	31	8/17	1.23	1.55	15.9	3.96	70.6	52.3	3.73	0.47	1.51
6	9.3	33	8/19	1.23	1.55	14.6	4.03	63.7	52.6	3.31	0.48	1.59
	Av.						4.00	67.0	52.4	3.52	0.48	1.55
10	15.3	25	8/3	1.24	1.65	17.3	4.02	241.	65.5	10.10	0.34	1.09
11	15.3	27	8/9	1.23	1.60	19.8	4.00	329.	67.0	13.51	0.33	1.07
	Av.						4.01	285.	66.2	11.80	0.34	1.08
21	18.7	39	9/2	1.35	1.67	9.4	4.17	171.	63.0	7.16	0.39	1.31
21	18.7	41	9/28	1.35	1.67	15.3	4.15	232.	66.5	9.25	0.35	1.20
	Av.						4.16	201.5	64.7	8.20	0.37	1.25
19	22.5	35	8/23	1.21	1.40	10.6	4.11	218.	50.6	11.56	0.51	1.69
1	21.9	37	8/26	1.28	1.63	6.9	4.11	248.	57.1	11.79	0.43	1.45
	Av.						4.11	233.	53.8	11.67	0.47	1.57

Table 5.--Summary of data from rain simulator - wet soil runs on the various slopes.

Plot No.	Slope	Run No.	Date	Volume Weights		Soil Moisture 0 - 6 inches	Intensity	Soil Loss per Plot	Water Loss	Density per Cu. ft.	Infiltration	
				0-6 in.	6-12 in.						Total	Average Rate
	Pct.		1938			Pct.	In.per Hr.	Lbs.	Pct.	Lbs.	In.	In.per Hour
9	2.9	30	8/12	1.19	1.45	22.8	4.17	22.4	82.5	0.71	0.18	0.54
9	2.9	44	10/4	1.19	1.45	24.6	4.08	33.5	79.3	1.14	0.21	0.65
	Av.						4.12	27.9	80.9	.94	0.20	0.59
8	4.2	23	7/25	1.27	1.42	15.3	4.04	55.7	83.3	1.83	0.17	0.52
8	4.2	53	10/14	1.27	1.42	18.1	4.11	52.3	76.4	1.83	0.24	0.75
	Av.						4.08	54.0	79.8	1.83	0.20	0.63
7	9.3	32	8/17	1.23	1.55	18.3	3.96	133.	81.2	4.55	0.19	0.59
6	9.3	34	8/19	1.23	1.55	18.1	4.03	122.	83.7	3.99	0.17	0.53
	Av.						4.00	128.	82.4	4.27	0.18	0.56
10	15.3	26	8/3	1.24	1.65	19.8	4.02	229.	82.5	7.61	0.17	0.52
11	15.3	28	8/9	1.23	1.60	24.3	4.00	227.	80.0	7.82	0.20	0.62
	Av.						4.01	228.	81.2	7.71	0.18	0.57
21	18.7	40	9/2	1.35	1.67	14.3	4.17	233.	84.0	7.31	0.17	0.53
21	18.7	42	9/28	1.35	1.67	18.3	4.15	341.	81.5	11.06	0.19	0.62
	Av.						4.16	287.	82.8	9.18	0.18	0.57
19	22.5	36	8/23	1.21	1.40	15.6	4.11	391.	79.8	13.19	0.21	0.66
1	21.9	38	8/26	1.28	1.63	12.4	4.11	359.	85.2	11.44	0.16	0.49
	Av.						4.11	375.	82.5	12.31	0.18	0.57

plot, to 0.68 inches for the 22.5 percent plot. Rates computed in this manner were lower than the average rates shown in table 5, as would be expected. The high intake of water at the beginning of the runs before the soil was wet, was ruled out in these equilibrium rates.

Neither the individual nor the average of the two equilibrium infiltration rates for each slope exhibit any consistant relationship with slope. The average rates do show a slightly higher rate on the two lower slopes, but no definite trend is indicated. The average infiltration rates might be expected to vary with slope because of the slight decrease in infiltration opportunity accompanying increase in slope. A decrease in depression storage and a more rapid draining of the plot would be expected to accompany increase in slope. Further studies may bring out a slight relationship between slope and infiltration. Duley and Kelly (3) report a tendency for intake of water to decrease slightly with increase of slope. The work of Duley and Hays (2) indicates that degree of slope has only a slight effect on infiltration. Neal (10) working with an artificial soil profile and various intensities and amounts of "rainfall", reports that "as a whole, the data indicate that for slopes from 1 to 16 percent, the rate of infiltration is not a function of slope".

Table 6.—Infiltration rate and ratio of run-off rate to rainfall intensity for all slopes

Run No.	Plot Slope	i Rainfall Rate	q Average Equilibrium Run-off Rate	i - q Infil-tration Rate	i - q Averages by Slopes	q/i Ratio of Run-off Rate to Rainfall	q/i Average
	Pct.	Inches per Hour	Inches per Hour	Inches per Hour	Inches per Hour		
30	2.9	4.17	3.66	0.51		0.877	
44	2.9	4.08	3.66	0.42	0.47	.895	0.886
53	4.2	4.11	3.53	0.58	0.58	.859	.859
34	9.3	4.03	3.53	0.50		.874	
32	9.3	3.96	3.39	0.57	0.54	.856	.865
26	15.3	4.02	3.55	0.47		.883	
28	15.3	4.00	3.49	0.51	0.49	.872	.877
40	18.7	4.17	3.69	0.48		.884	
42	18.7	4.15	3.60	0.55	0.52	.869	.877
36	22.2	4.11	3.51	0.60		.854	
38	22.2	4.06	3.64	0.42	0.51	.896	.875

Percentage of run-off from the various slopes.

As there was no trend toward a slope-infiltration relationship, there was no evidence of a relationship between slope and run-off percentage. The run-off percentage for the dry runs were quite variable while those for the wet runs were very nearly the same for all slopes. There also appeared to be no consistent relationship between the percentage of run-off and the soil moisture content.

Neal (10) reported that increase in slope above one percent, apparently had little effect on the percentage of run-off. Data reported by Nichols and Sexton (11) indicate that run-off increases markedly with a slope increase from 0 to 5 percent and gradually thereafter. Diseker and Yoder (1) present data for fallow plots which show that increase in slope above 5 percent did not affect percentage of run-off. Duley and Hays (2) report a significant increase in run-off percentage as slope was increased to 4 percent; after 4 percent, a much slower rise. Horton (5) states that there is always some increase in run-off with increasing slope.

Rate of run-off from the various slopes.

Hydrographs of wet soil runs for various slopes are shown in figure 2. There was considerable difference in the rising stage of these curves and but little during the equilibrium period. Small differences in rates of run-off from the different slopes during this period, may be partially accounted for by small differences

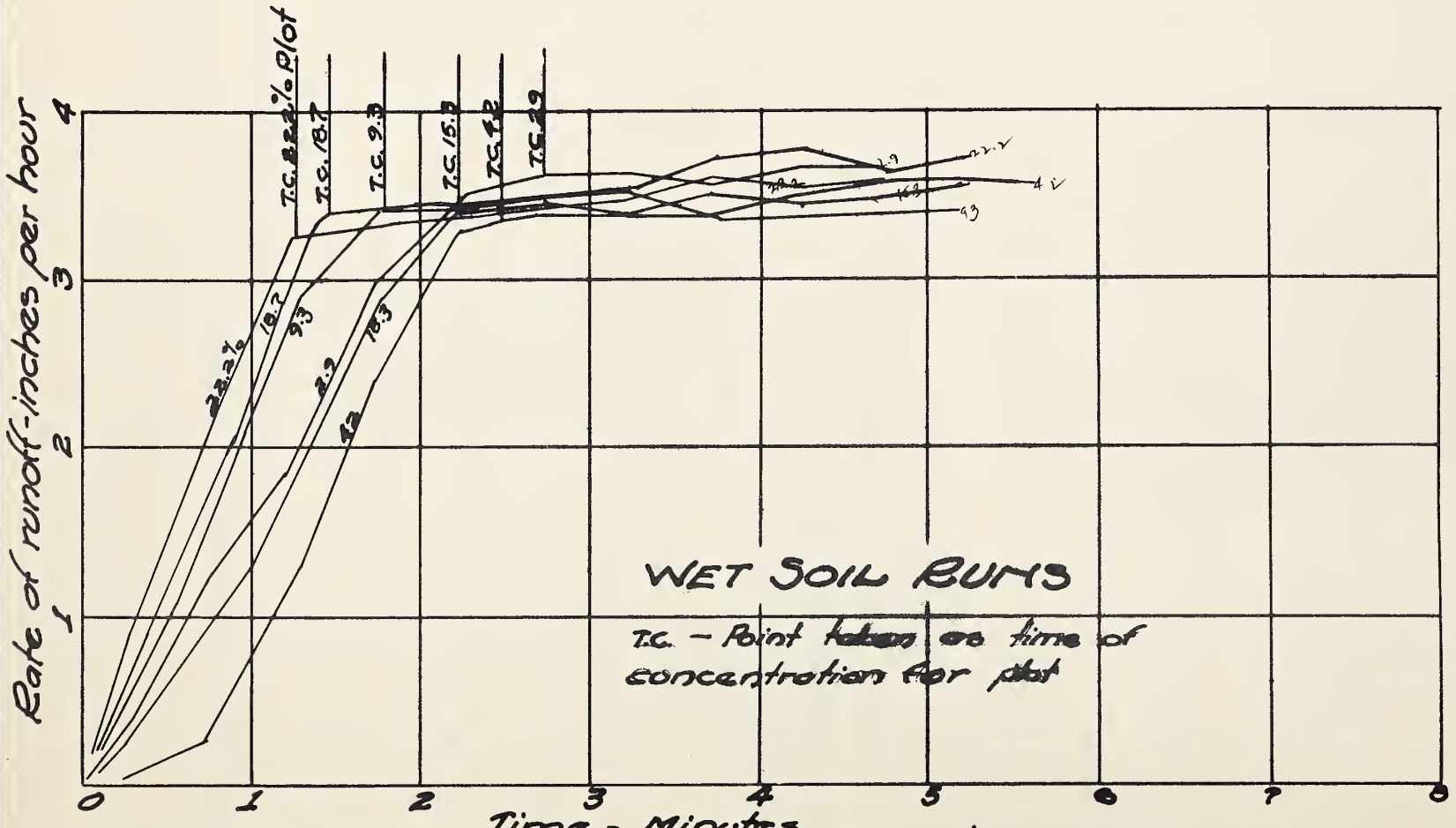

Figure 2 Relationship of rising stage of runoff graph to plot slope. Each curve is average of two runs.

in rainfall intensity. In order to eliminate the effect of these small variations in rainfall intensity, the average equilibrium rate of run-off for each slope was divided by the effective rainfall intensity and these results are shown in table 6. The rate of run-off after equilibrium flow was reached was essentially the same for all slopes. The run-off rate during equilibrium flow was rate of rainfall less rate of infiltration. No significant difference was found in the latter from low to high slopes and, as a result, run-off rates did not vary appreciably from slope to slope. The relationship between the rising stage and slope, may be observed in figure 3, showing hydrographs of the "burlap" runs.

Rate of soil loss from different slopes.

Rate of soil loss curves are presented in figure 4 and 5. Representative soil loss increments are shown in the sample tables in the appendix.

During the dry runs, erosion from the lower slopes assumed a fairly constant rate soon after run-off started; the rate of soil loss followed the rate of water loss rather closely. On the slopes greater than 9 percent, however, the rate of soil loss varied considerably. In general, it rose with the hydrograph and then increased more gradually to the end of the test. Exceptions to this rule obtained on one slope (15.3 percent) where the soil loss rate climbed very high at the beginning of the run and on plot 1 (22.5

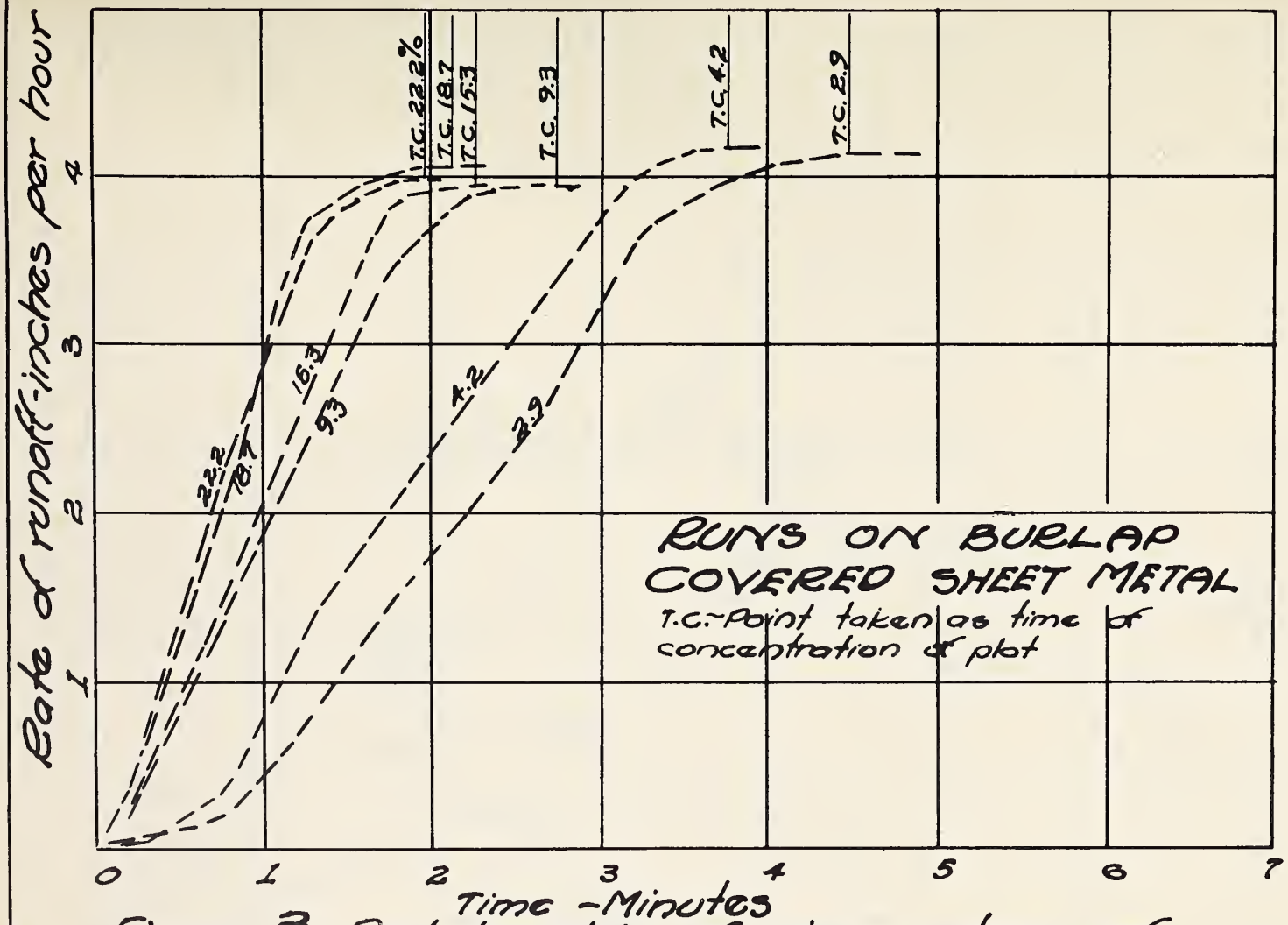

Figure 3 Relationship of rising stage of runoff graph to plot slope. Each curve is average of two runs.

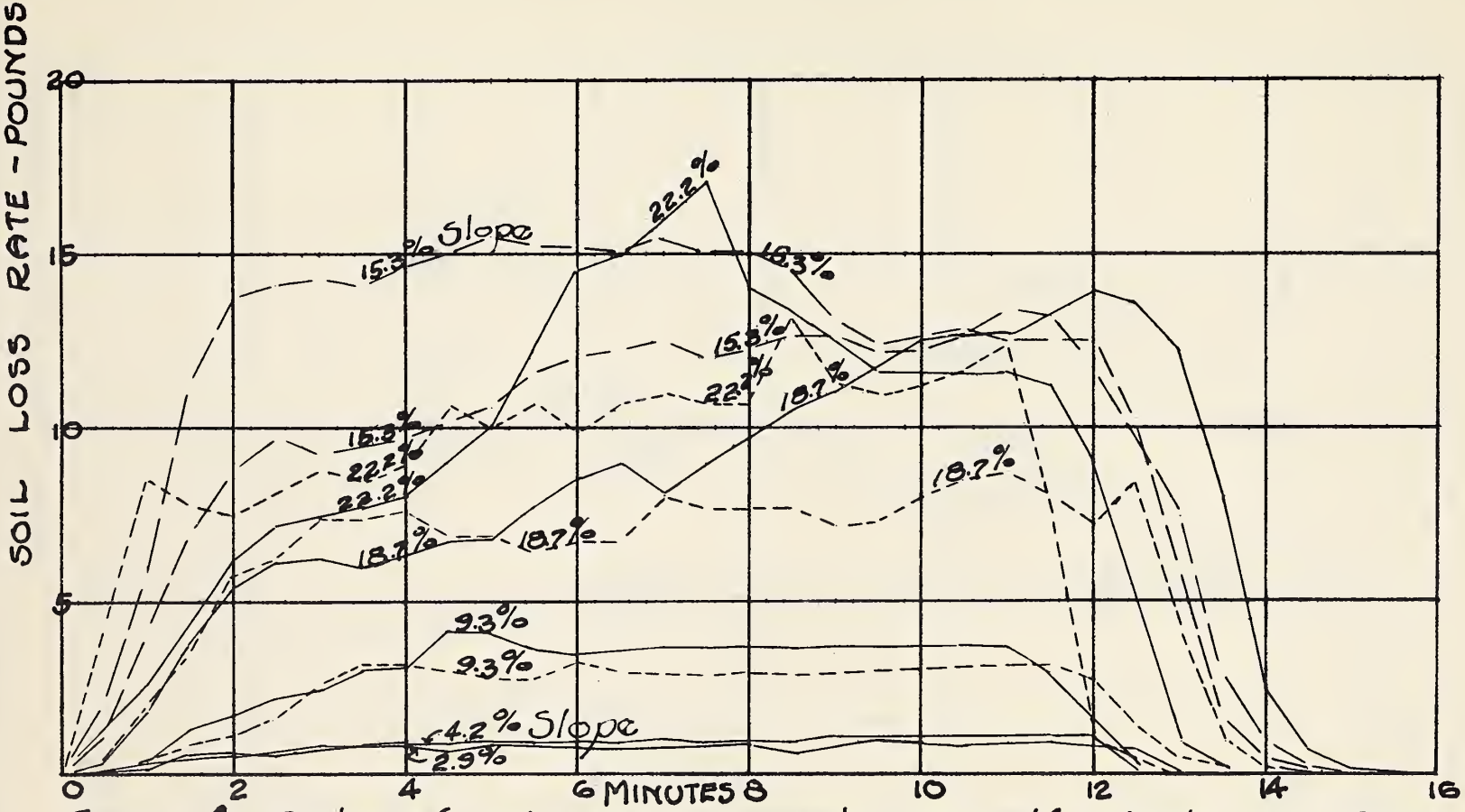

Figure 4 Rate of soil loss in pounds per half minute - Dry Runs

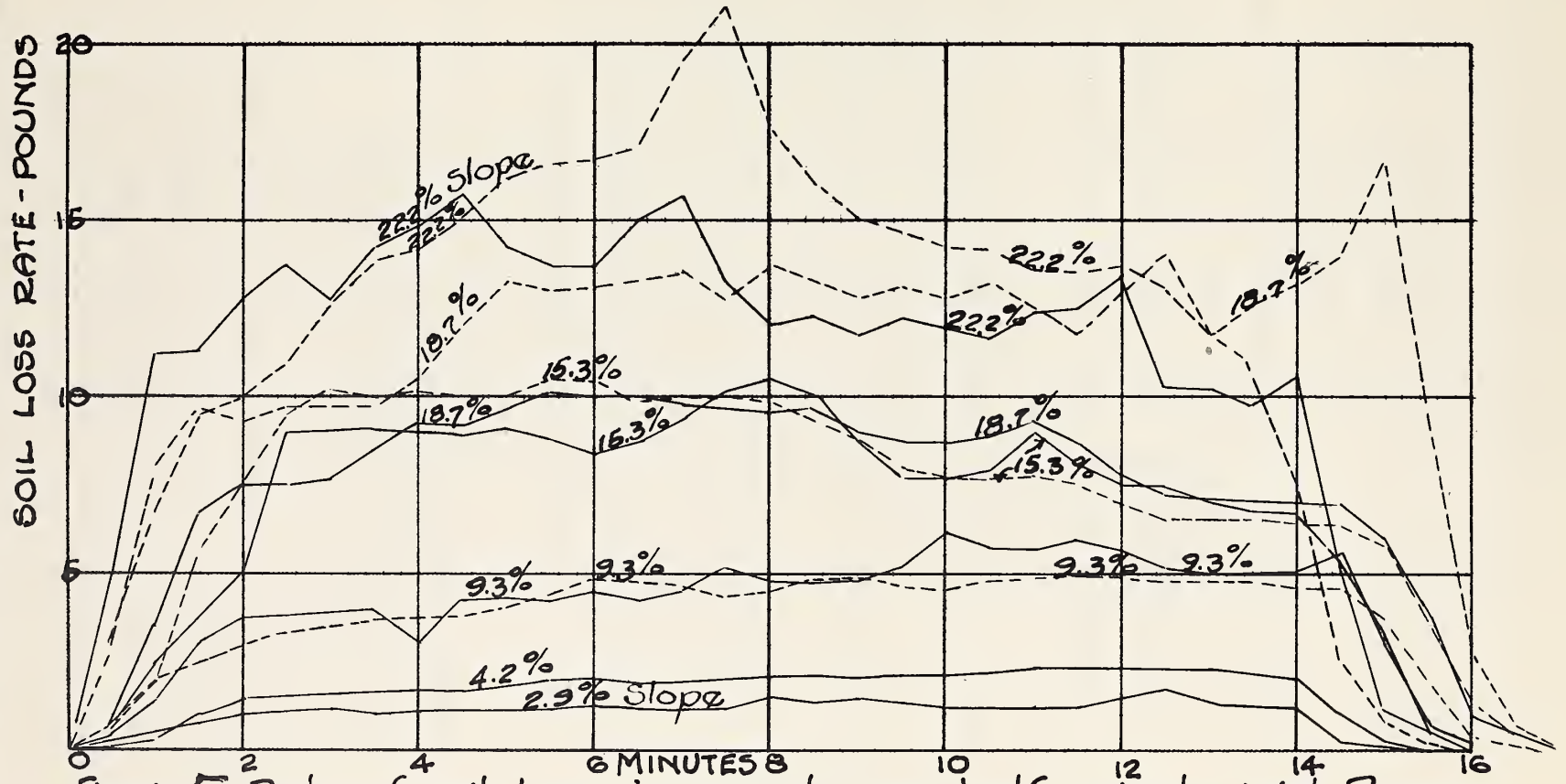

Figure 5. Rate of soil loss in pounds per half minute - Wet Runs

percent slope) where a high rate of soil loss occurred in the middle of the run. Gullying occurred on all of the steeper slopes and it would appear that, in general, the rate of soil loss continued to increase as these gullies formed.

During the wet runs on slopes up to and including the 9 percent, there was an indication of a slight rise in rate of soil loss after equilibrium run-off had begun. On the higher slopes, however, the soil curves for the wet runs all show a downward trend toward the end of the runs. It would appear that after the gullies (which occurred only on the steeper slopes) had cut to the depth of the loose cultivated soil, soil loss rate decreased. In general, rate of soil loss and rate of water loss reached equilibrium at the same time.

The density of run-off (unit of silt per unit of water) increased rapidly at first (more rapidly than the erosion rate) and then increased more gradually, reaching its maximum when equilibrium flow was established. (See figures 6 and 7.)

Comparison of losses from wet and dry runs.

Soil losses were considerably lower from the dry runs than from the wet runs. Apparently this difference was caused largely by the difference in amount of run-off. Although density from the various runs was quite variable, there probably is no significant difference between the density of the run-off from the dry runs and that of the wet runs. This would indicate that the loose soil condition obtained during the dry runs was not conducive to greater erosion.

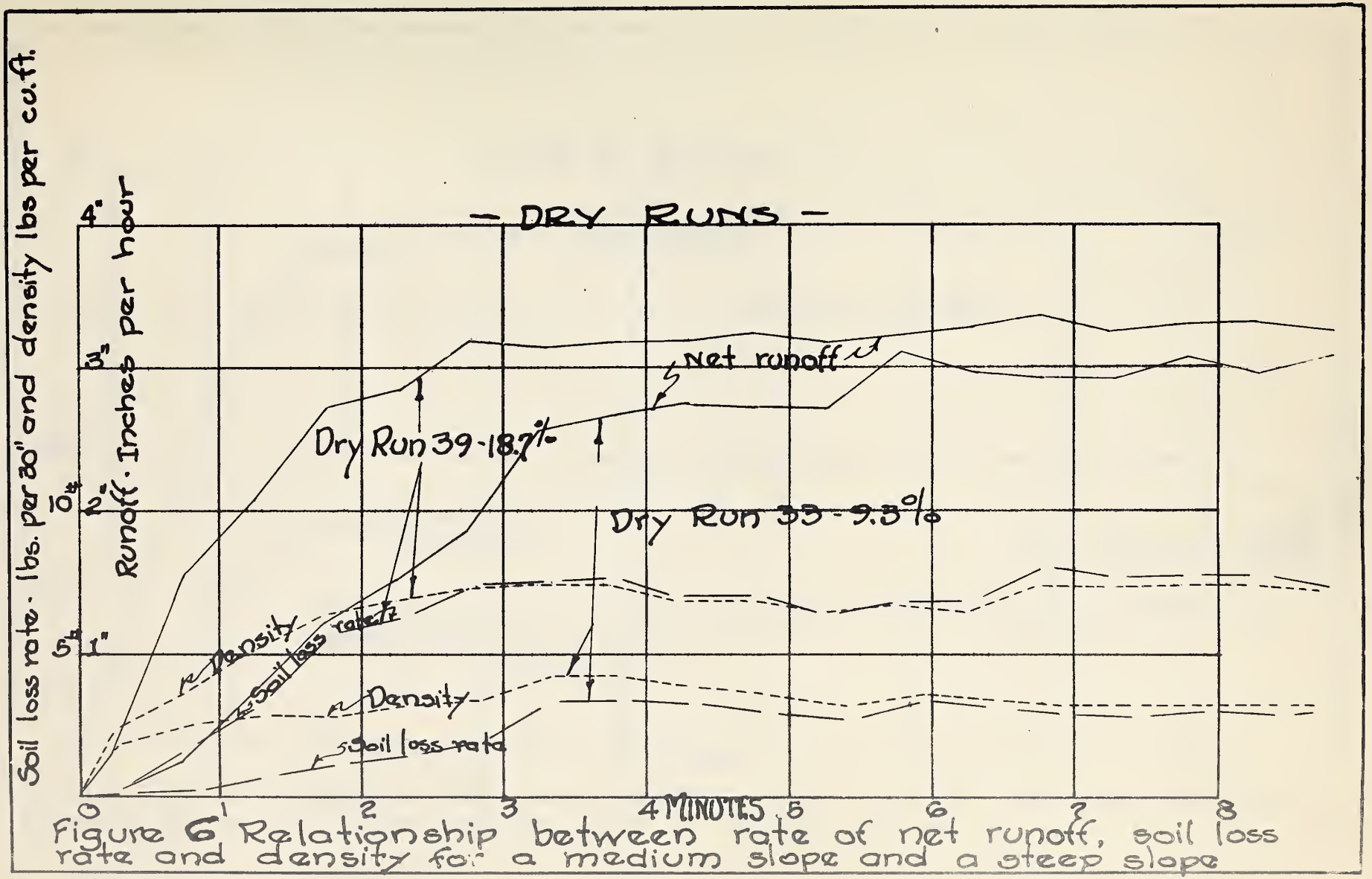

Figure 6 Relationship between rate of net runoff, soil loss rate and density for a medium slope and a steep slope

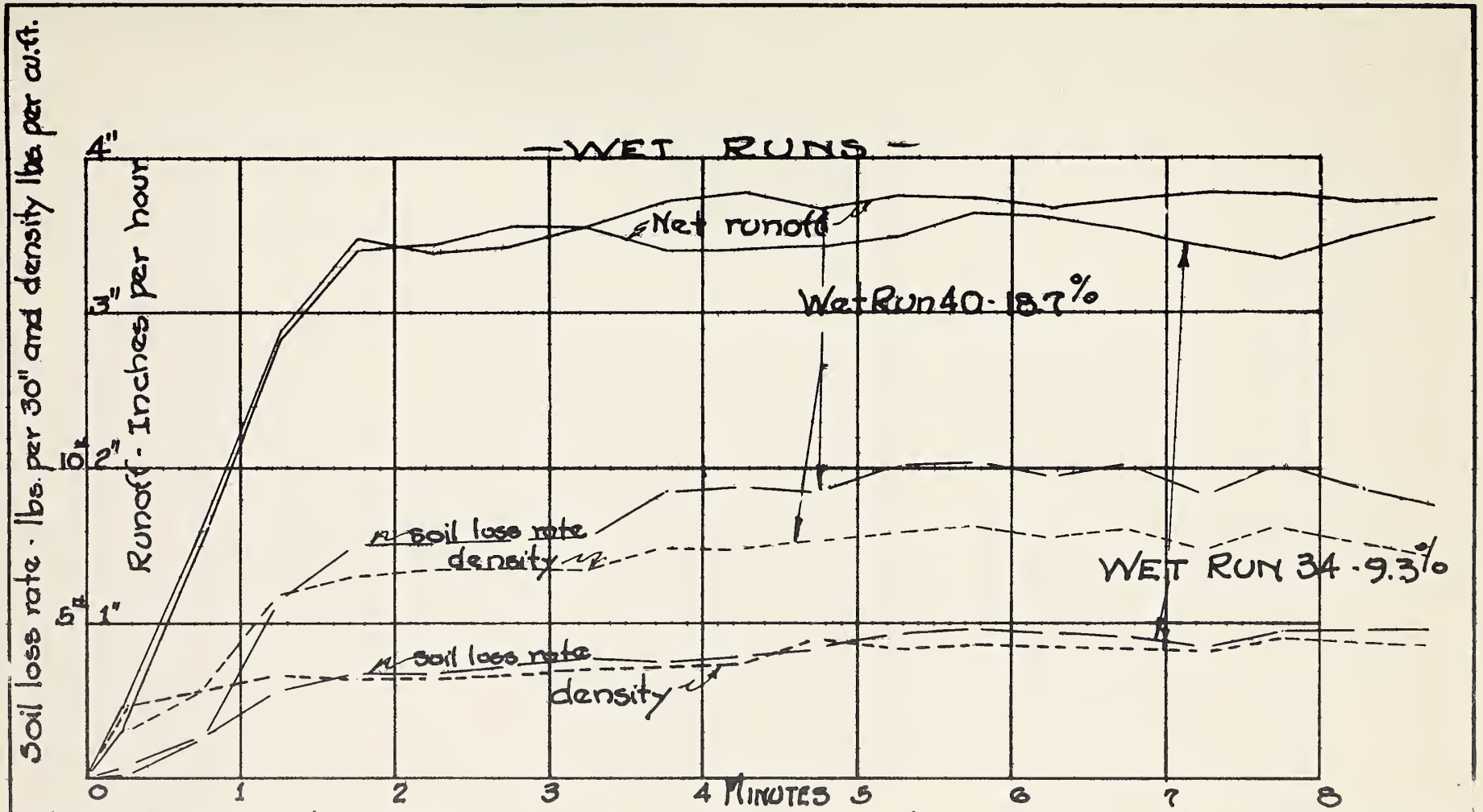

Figure 7. Relationship between rate of net runoff, soil loss rate and density for a medium slope and a steep slope.

Soil loss-slope relationship.

Soil losses, in general, increased progressively with increased slope in both dry and wet runs. One exception to this rule occurred in the dry runs on the 15.3 percent slopes where the soil loss was very high. The reason for this exception is not clear since the soil moisture content and volume weight of the soil on this slope were not very different from those of the other plots. The intensity of water application and timing were well controlled for all plots.

The relationship between soil losses and slope is shown in the logarithmic diagram, figure 8. The curves were fitted by least squares.

The wet run losses indicate a straight-line trend in the diagram. The dry run losses were somewhat more variable, but, with the exception of the loss from the 15.3 percent slope, indicate a curve with nearly the same exponent as that of the wet runs. The formulae for the two curves are:

For 1 inch of rain at 4 inches per hour on

Wet soil runs $E = 8.23S^{1.223}$

Dry soil runs $E = 4.84S^{1.298}$

where E is erosion in pounds per plot and S is slope in percent.

Neal (10) found erosion to vary as the 0.7 power of the slope. His erosion equation for 1 inch of rain on any slope is:

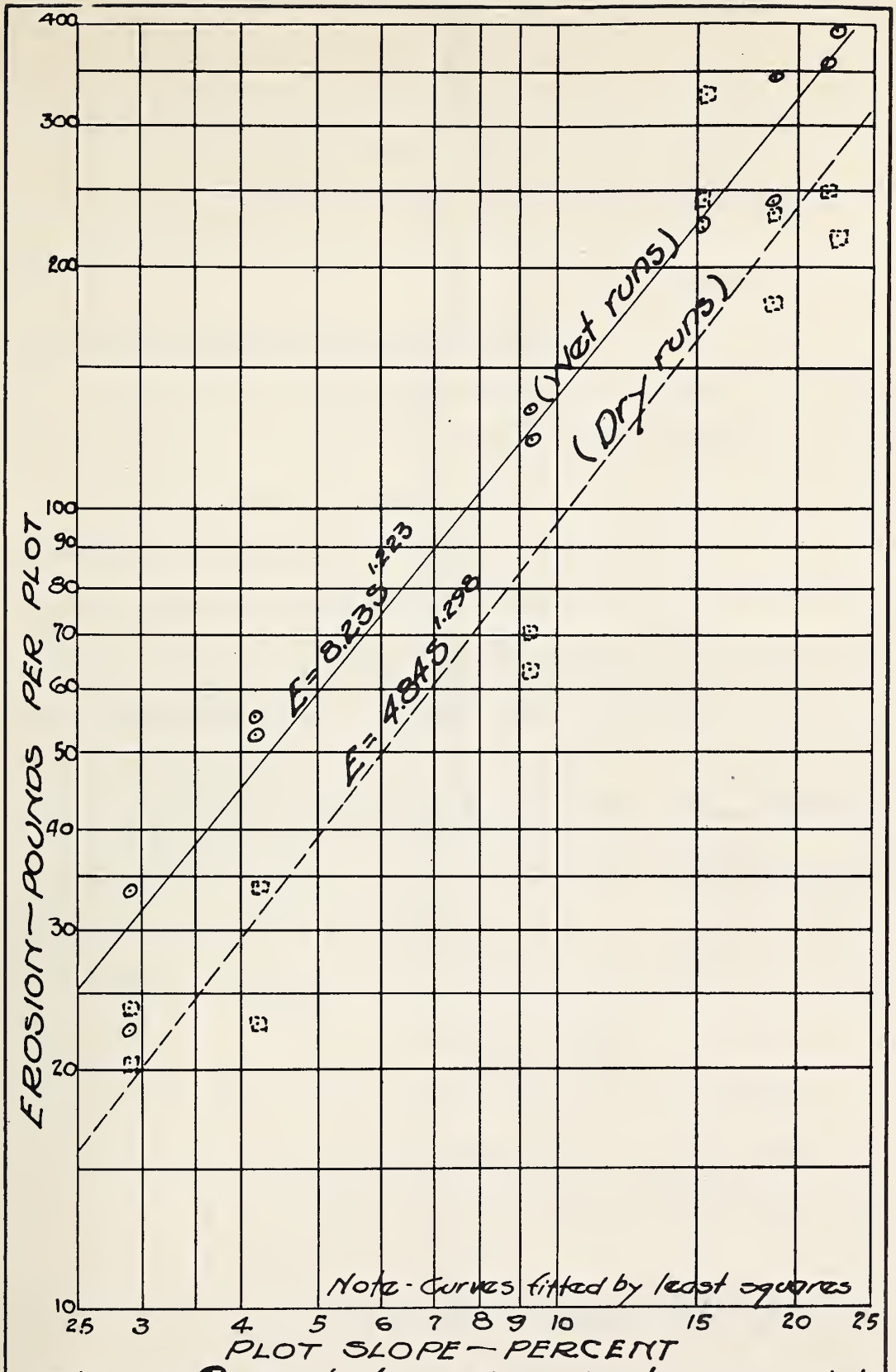

Figure 8 Relationship between plot slope and erosion for one inch of rainfall at 4" per hour

$$E = K_2 S^{0.7} I^{1.2}$$

K_2 is a constant and I is rainfall intensity in inches per hour.

Velocity of run-off as related to slope.

Since rate of run-off was essentially the same for all slopes, it would appear that the increase in erosion accompanying increase in slope, came about, at least partially, as a result of increased velocity of overland flow. Doubtless there was also a lessened erosion resistance accompanying increase in slope. It is well established, however, that the velocity of channel flow increases exponentially with slope. To investigate overland velocity as a causal factor in the slope-soil loss relationship, velocities for the burlap runs were computed from surface detention formula from Horton (4 and 8) and for the burlap and soil runs by time of concentration. The formula using surface detention is:

$$V_{av.} = \frac{3M}{(2 + 3M)} \quad \frac{q_s A}{W \frac{d_a \text{ or } d_n}{12} \left(\frac{M + 1}{M}\right)}$$

The following are the definitions of symbols used:

$V_{av.}$ = Average overland velocity in feet per second.

M = The exponent in Horton's (4, 6 and 7) overland flow equation $q_s = K_s d^M$.

q_s = The rate of run-off in inches per hour or cubic feet per second per acre approximately.

A = Area of plot in acres.

W = Width of plot in feet.

d_a = Average surface detention - depth in inches.

d_n = Net surface detention - depth in inches.

M expresses the exponential relationship between surface detention and rate of run-off during the rising stage of the hydrograph and its magnitude, according to Horton (4 and 6), reflects the type of flow, whether turbulent, partially turbulent or laminar. M was calculated for each run as follows: Values of surface detention taken from the tabulated hydrograph data, were plotted against corresponding values of rate of run-off on a logarithmic diagram for the rising stage of the run-off graph. The plotted points fell, in general, on a straight line, the slope of which is defined as M. It was approximately 2.0, which indicated 75 percent turbulent flow.

Average surface detention (d_a) is average depth of the water on the plot during run-off. It was computed according to Horton's (4, 6, 7 and 8) method; mass supply (mass rainfall less mass infiltration) less mass run-off. Net surface detention (d_n) was obtained by subtracting initial detendion (d_o) from d_a. Initial surface detention is the water which accumulated on the surface in depressions (depression storage) before run-off started.

Average surface detention is usually used in calculating velocity of overland flow. Although some of this water (initial

detention, d_o) may be held in depressions, as Horton (7) points out, surface flow takes place through these depressions. On the theory that the water falling on the burlap plot before run-off started, was held in the fabric and did not function in overland flow, net surface detention (d_n) was used in the calculation of velocity. Velocities were calculated also on the basis of average surface detention (d_a) for comparison. The surface detention, rate of run-off and values of M and the resulting velocities for the burlap runs, are shown in table 7.

Velocities computed from both d_n and d_a are plotted in relation to slope on the logarithmic diagram, figure 9. The relationship is exponential in each case but the exponents of the two curves are somewhat different. Since the burlap still held considerable water when run-off had completely stopped, it would seem that this water held as initial detention, did not function in overland flow and should not enter a computation of velocity.

Velocity of overland flow was not calculated for the soil runs by the surface detention method. Because of the fact that infiltration took place at varying rates during the dry runs (high at the start of the test and decreasing thereafter) it was not possible to compute, accurately, the surface detention using the average value for infiltration. However, on the assumption that infiltration had become constant on the wet runs, surface detention

Table 7.—Surface detention and values of M for the burlap runs

Slope	Run No.	d_a	d_o	d_n ($d_a - d_o$)	M	q_s Equilibrium	Average Velocity	
							d_n Basis	d_a Basis
Percent		Inches	Inches	Inches			Ft.per sec.	Ft.per sec.
2.9	29B	0.220	0.052	0.168	2.34	4.125		
2.9	43B	0.248	0.102	0.146	2.09	4.080		
Average 2.9		0.234		0.159		4.102	0.258	0.175
4.2	52B	0.207	0.076	0.131	1.92	4.210	0.321	0.203
9.3	33B	0.156	0.084	0.072	1.95	4.013		
9.3	31B	0.150	0.071	0.079	2.00	3.925		
Average 9.3		0.153		0.076		3.969	0.526	0.259
15.3	27B	0.137	0.078	0.059	1.80	4.012		
15.3	25B	0.134	0.066	0.068	2.07	3.952		
Av. 15.3		0.136		0.063		3.982	0.627	0.294
18.7	41B	0.136	0.081	0.055	1.87	4.152		
18.7	39B	0.127	0.070	0.057	2.37	4.174		
Av. 18.7		0.132		0.056		4.163	0.743	0.318
22.2	37B	0.120	0.067	0.053	2.25	4.039		
22.2	35B	0.119	0.068	0.051	2.00	4.110		
Av. 22.2		0.120		0.052		4.074	0.783	0.341

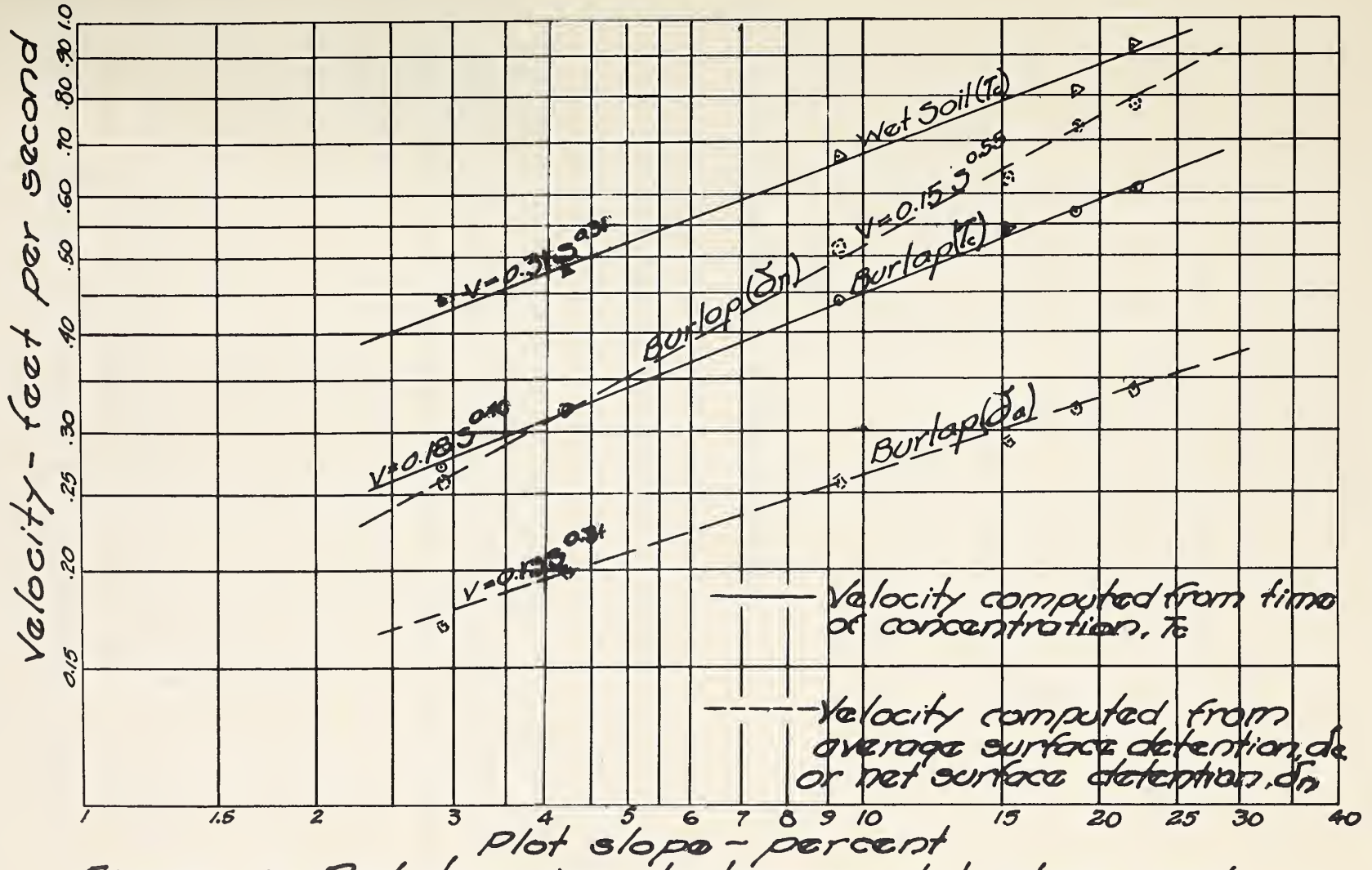

Figure 9. Relationship between plot slope and average overland velocity on burlap and on soil

values for them were computed (see table 3). The values of net surface detention (d_n) do not show any constant relationship with slope. There is some evidence, however, that surface detention tends to decrease on the steeper slopes indicating an increase in velocity with increase in slope. Because of uncontrolled variables, a greater number of runs would be required to establish a velocity-slope relationship on soil by this method.

Velocity was computed also from time of concentration as follows: $V = \frac{L_o}{t_c}$

V = Velocity in feet per second.

L_o = Length of plot in feet.

t_c = Time of concentration in seconds.

The time of concentration, beginning when run-off started and ending when run-off reached equilibrium, was determined from the hydrograph. Since it was difficult to determine the exact point where rate of run-off reached equilibrium, the concentration times for the various runs were approximate.

The relation between slope and the t_c velocities on burlap and on wet soil, is shown in figure 9. All curves in this figure were fitted by least squares except the burlap d_n curve. The t_c velocity on burlap is represented by the equation $V = 0.18S^{0.40}$, where V is velocity in feet per second and S is plot slope in percent. Velocity (t_c) on wet soil is represented by the equation

Table 8.--Surface detention on the wet soil runs

Slope	d_a	d_o	d_n
Pct.			
2.9	0.116	0.046	0.070
	0.128	0.076	0.052
Av.	0.122	0.061	0.061
4.2	0.122	0.047	0.075
9.3	0.085	0.037	0.048
	0.082	0.029	0.053
Av.	0.084	0.033	0.050
15.3	0.101	0.029	0.072
	0.101	0.038	0.063
Av.	0.101	0.034	0.067
18.7	0.087	0.030	0.057
	0.087	0.044	0.043
Av.	0.087	0.037	0.050
22.2	0.092	0.053	0.039
	0.078	0.042	0.036
Av.	0.085	0.048	0.038

$V = 0.31S^{0.31}$. It is to be noted that the exponent of the curve for velocity computed from d_a, and those in the equations for velocity from time of concentration, are somewhat similar. These three exponents are considerably lower than that for the velocity based on net surface detention. This matter will be given further study.

The relationship between velocity of run-off and soil loss.

The relation of the velocities discussed above, to the soil loss from the various slopes, is shown in figure 10. Although the velocities on the burlap were probably not the same as those on soil, the relationship of the burlap velocities to soil loss on the various slopes is of interest. The plotted points fall nearly in straight lines, indicating an exponential function for velocity. The formulae for the four curves are:

For burlap velocity, $E_{(erosion)} = K V^{2.35}$ (velocity from d_n)

For burlap velocity, $E = K V^{3.65}$ (velocity from d_a)

For burlap velocity, $E = K V^{3.08}$ (velocity from t_c)

For wet soil velocity, $E = 529.8V^{2.96}$ (velocity from t_c) 1/

It has been stated that erosive power of running water varies as the second power of velocity, and the transporting power varies

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1/ This equation was derived by least squares

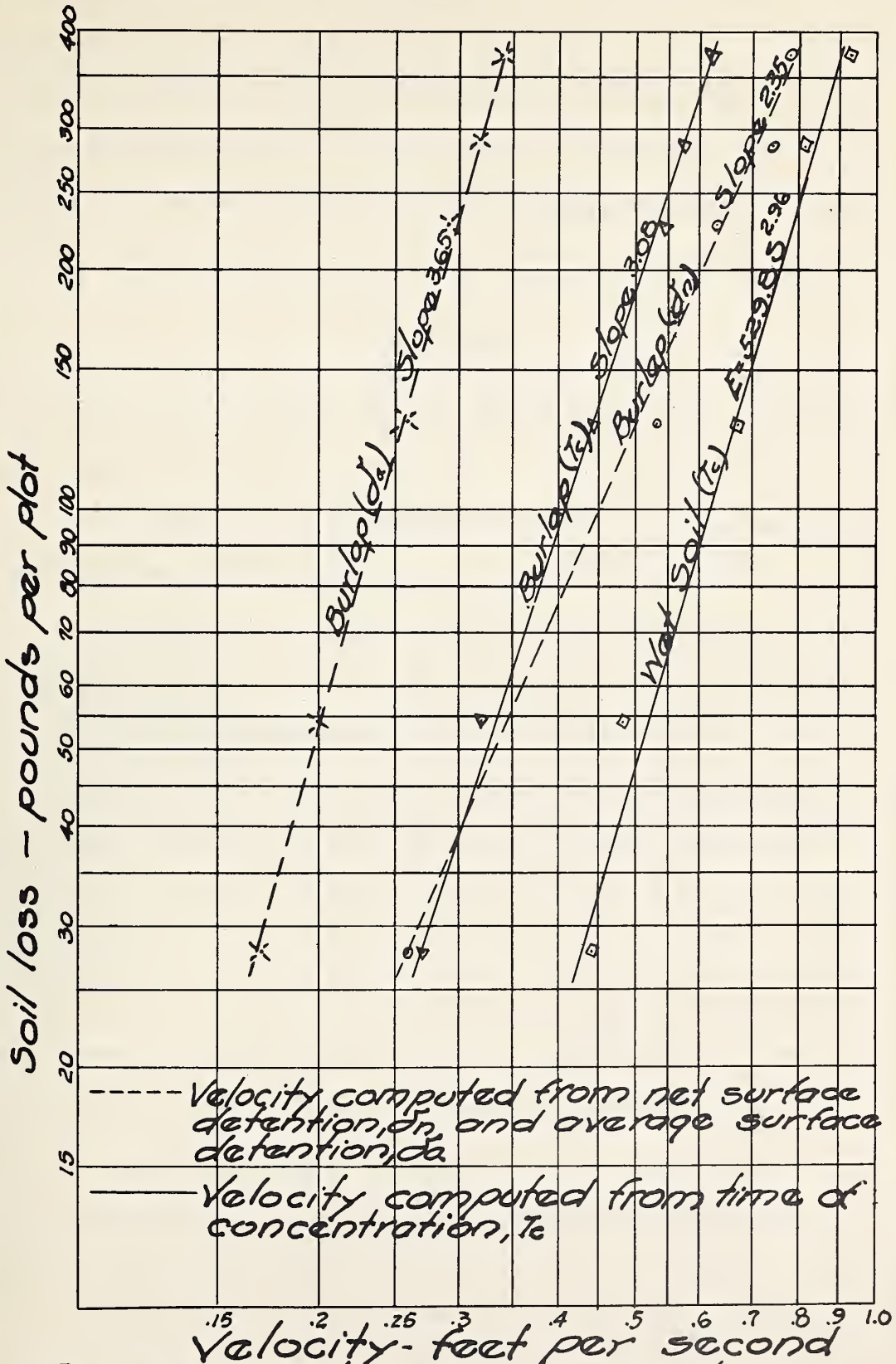

Figure 10. Relationship of velocity on burlap covered sheet metal and on wet soil to soil loss on wet soil runs

as the sixth power of velocity (Leconte (9). It would appear that some power between these two limits might be expected in this experiment. As indicated before, the relationship between velocity (by t_c) on wet soil and soil loss, was expressed by the 2.96 power.

Conclusions

1. There was apparently no relation between the infiltration rates found in the tests, and slope.

2. There was no sifnificant difference in the percentage of run-off from the different slopes.

3. There was no significant difference in the rate of run-off from the different slopes. The rate of run-off was essentially constant after equilibrium flow had been established.

4. Soil loss exhibited an exponential relationship with slope. The slope exponent for both the wet and dry runs, when one inch of water was applied at four inches per hour, was of the order of 1.2.

5. The velocity of overland flow as computed for the burlap runs, and velocities derived from time of concentration on both burlap and soil runs, increased exponentially with slope. The slope exponent for the velocity (by d_n) for the burlap runs, was 0.55; for velocity by t_c on burlap was 0.40 and for velocity by t_c on the wet soil was 0.31.

6. Soil losses exhibited an exponential relationship to velocity. The slope exponents ranged from 2.35 to 3.65 for the various velocity values.

7. The rates of soil loss from the lower slopes during both the wet and dry runs were quite constant during equilibrium flow. On the steeper slopes, the dry run loss-rate tended to increase during this period, whereas the wet run loss-rate decreased slightly. Increases in rate of soil loss during the dry runs seemed to accompany the formation of gullies.

8. The density of run-off for the dry runs was not significantly different from the density for the wet runs. The difference in total soil loss was caused by differences in amount of run-off.

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APPENDIX A

Description of Rain Simulator Apparatus

The nozzle was constructed from a 3/4" x 3" piece of brass pipe. One end of this pipe was closed by a brass disc fitted and soldered in place. A small brass cup-shaped tip (5/16 inch in diameter at its base) was soldered to an opening in the center of this disc. A transverse slot cut in the upper side of the tip formed the delivery orifice of the nozzle. Another sheet brass disc with a small hole in its center, was placed inside the tube about one inch from the orifice. This internal disc set up a marked degree of turbulence in the water which caused a wide lateral distribution of the spray. All nozzle parts were carefully machined and fitted to a tolerance of 0.005 inch or less.

The nozzles were attached at 42-inch intervals by tees to sections of 1-inch pipe, mounted on 1" x 8" boards, 11 feet long. Each of these boards carried 2 parallel lines of pipe with the 3 nozzles on one line of pipe interspaced with the 3 on the other (see photograph). The distance between nozzles was one foot and 9 inches.

The long axis of the nozzles on the upper supply pipe was adjusted to one degree below horizontal and those on the lower line, two degrees above horizontal. The water was discharged from the nozzle in an upward and outward direction and reached a maximum height of three feet above the nozzles. Each nozzle board was equipped with a sheet metal hood, mounted on hinges so that it could be lowered over the nozzles. When this deflecting hood was

down, all water from the nozzles was caused to fall downward outside the plot. Raising the deflector, allowed the water to fall on the plot. Each side of the machine was equipped with seven of the previously described nozzle boards, placed end to end except for a slight overlap at the supporting post. (The total length of the apparatus was approximately 80 feet).

The nozzle boards and their pipe lines were mounted in a horizontal position (adjusted by leveling) on 2" x 4" posts 14 feet high so that the lower nozzle pipe line, at its mid-point, was 9 feet above the surface of the plot. The 2" x 4" posts supporting the nozzle boards were connected across the top by horizontal braces and along the plot by both horizontal and "X" braces. It was necessary that these supporting uprights be accurately plumbed in order to maintain the proper angle on the nozzles. Guy ropes were used to add stability to the framework.

Long skids of 2" x 6" lumber with flexible joints every 12 feet were bolted to the lower ends of the 2" x 4" supporting posts to facilitate moving. Canvas hung from the top longitudinal braces covered the sides and ends of the framework to partially obviate the effect of wind.

Two 1-1/2 inch pipes along the sides of the framework supplied water to each nozzle board assembly separately, through short sections of 1-inch hose. The water pressure on each set of 6 nozzles was measured by gages installed between this hose and the

supply line to the pipes which carried the nozzle and was regulated by a valve at the junction of the hose and main supply line. Another valve on the back of the nozzle assembly made it possible to cut off the lower row of nozzles.

The two feed lines along the side of the apparatus were joined by a tee to a 2-inch fire hose which led to the pump. The pumping unit used was a 2-inch centrifugal directly connected to a 2-1/2 h.p. single cylinder gasoline engine. The unit mounted on a small base was easily handled by two men.

The seven movable deflectors on the nozzle boards of each side of the apparatus were connected by means of ropes and pulleys to a lever on the same side of the framework so that all deflectors could be operated simultaneously by two men.

Moving the apparatus

During the early part of the summer the apparatus was entirely taken apart and reassembled whenever a move was necessary. This procedure required about 15 man-days of labor. Later, a method of moving the machine on skids - one half at a time - with a tractor was devised. The labor necessary was reduced to about 4 or 5 man-days.

APPENDIX B.

Sample tables of original and computed data
Explanation of tables

In the "time" column, the first figure is time of beginning of rain and the second figure is time of beginning of run-off. In general, time is shown by thirty-second intervals from run-off starting time. This column is original data taken during the runs with an ordinary watch and a stop watch.

The quantities in the "cumulative rainfall" column were calculated in cubic feet from the rain intensity and length of the time interval.

The "cumulative infiltration" column was calculated from average infiltration rate. The average rate was obtained from the difference between total rainfall and total run-off and the time from beginning of rainfall to end of run-off. In the dry runs, infiltration rate was probably much higher than this average figure at the beginning of the run and gradually diminished as water was applied. For this reason, a high degree of significance cannot be assigned to the infiltration figures for the dry runs.

"Cumulative run-off" was computed for each time shown from the run-off increments caught between the times shown.

"Run-off increments" were measured directly in the field in cubic feet. Each increment represents an individual container which

was under the run-off spout for thirty seconds.

"Run-off - inches per hour" was calculated from the volume of the individual increments in cubic feet. (1.2 cubic feet per 30-second interval, equals 4 inches per hour.)

"Surface detention" was calculated as the difference between total rainfall and the sum of total infiltration and total run-off at each time shown. It is shown in cubic feet and also in equivalent inches of depth over the 1/100 acre plot. (0.363 cubic feet equals 0.01 inch depth.)

In the last column is shown the amount of soil loss per 30-second interval of time determined by analysis of samples split from the run-off increments.

Plot No. 7 Slope 9.3% Date 8/17/38 Run No. B-31 Intensity 3.925 Duration 15 min.

Plot Moisture 0-6"____ 6-12"____ 12-18"____ Vol. Wt. Upper 6"____ Lower 6"____ For soil runs 31-32

Burlap Run

Sheet No. 1 of 2 sheets

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft.	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
9-24-00	0.000	Rain start						
9-25-05	2.572	R.O. start	0.000			2.572	0.0708	
	1.187			0.046	0.15			
9-25-35	3.759		0.046			3.713	0.1023	
				0.338	1.13			
9-26-05	4.946		0.384			4.562	0.1257	
				0.683	2.28			
9-26-35	6.133		1.067			5.066	0.1396	
				0.985	3.28			
9-27-05	7.320		2.052			5.268	0.1451	
				1.185	3.95			
9-27-35	8.507		3.237			5.270	0.1452	
				1.190	3.97			
9-28-05	9.694		4.427			5.269	0.1452	
				1.162	3.87			
9-28-35	10.881		5.589			5.292	0.1458	
				1.151	3.84			
9-29-05	12.068		6.740			5.328	0.1468	
				1.206	4.02			
9-29-35	13.255		7.946			5.309	0.1462	
				1.161	3.87			
9-30-05	14.442		9.107			5.335	0.1470	
				1.143	3.81			
9-30-35	15.629		10.250			5.379	0.1482	
				1.164	3.88			
9-31-05	16.816	No infiltration. Burlap on sheet metal.	11.414			5.402	0.1488	
				1.185	3.95			
9-31-35	18.003		12.599			5.404	0.1489	
				1.113	3.71			
9-32-05	19.190		13.712			5.478	0.1509	
				1.200	4.00			
9-32-35	20.377		14.912			5.465	0.1506	
				1.141	3.80			
9-33-05	21.564		16.053			5.511	0.1518	
				1.252	4.17			
9-33-35	22.751		17.305			5.446	0.1500	
				1.159	3.86			
9-34-05	23.938		18.464			5.474	0.1508	
				1.174	3.91			
9-34-35	25.125		19.638			5.487	0.1512	
				1.192	3.97			
9-35-05	26.312		20.830			5.482	0.1510	
				1.220	4.07			
9-35-35	27.499		22.050			5.449	0.1501	
				1.198	3.99			
9-36-05	28.686		23.248			5.438	0.1498	

Plot No. 7 Slope 9.3% Date 8/17/38 Run No. B-31 Intensity 3.925 Duration 15 min.

Plot Moisture 0-6"_____ 6-12"_____ 12-18"_____ Vol. Wt. Upper 6"_____ Lower 6"_____ For soil runs 31-32

Sheet No. 2 of 2 sheets

Burlap Run - continued

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft.	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
				1.221	4.07			
9-36-35	29.873		24.469			5.404	0.1489	
				1.141	3.80			
9-37-05	31.060		25.610			5.450	0.1501	
				1.166	3.89			
9-37-35	32.247		26.776			5.471	0.1507	
				1.169	3.90			
9-38-05	33.434		27.945			5.489	0.1512	
				1.202	4.01			
9-38-35	34.621		29.147			5.474	0.1508	
				0.977	3.91			
9-39-00	35.609	Rain stop	30.124			5.485	0.1511	
				0.195	3.90			
9-39-05			30.319			5.290	0.1457	
				0.988	3.29			
9-39-35			31.307			4,302	0.1185	
				0.615	2.05			
9-40-05			31.922			3.687	0.1016	
				0.429	1.43			
9-40-35			32.351			3.258	0.0898	
				0.314	1.05			
9-41-05			32.665			2.944	0.0811	
				0.240	0.80			
9-41-35			32.905			2.704	0.0745	
				0.187	0.62			
9-42-05			33.092			2.517	0.0693	
				0.147	0.49			
9-42-35			33.239			2.370	0.0653	
				0.119	0.40			
9-43-05			33.358			2.251	0.0620	
				0.099	0.33			
9-43-35			33.457			2.152	0.0593	
				0.082	0.27			
9-44-05			33.539			2.070	0.0570	
				0.068	0.23			
9-44-35			33.607			2.002	0.0552	
				0.064	0.21			
9-45-05	Timing stops		33.671			1.938	0.0534	
				1.090	---			
No time read			34.761			0.848	0.0234	
	Water in burlap		0.848					
			35.609					

Plot No. 7 Slope 9.3% Date 8/17/38 Run No. 31 Intensity 3.96" Duration 15 min.

Plot Moisture 0-6" 15.9, 6-12" 18.8, 12-18" 18.5

Vol. Wt. Upper 6" 1.23, Lower 6" 1.55

Dry Run

Sheet No. 1 of 2 sheets

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft.	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
12-57-00	0.000	0.000						
	8.785	3.369						
1-00-40	8.785	3.369	0.000			5.416	0.149	
	1.198	0.459		0.108	0.36			0.257
1-01-10	9.983	3.828	0.108			6.047	0.167	
				0.202	0.67			0.461
1-01-40	11.181	4.287	0.310			6.584	0.181	
				0.436	1.45			1.293
1-02-10	12.379	4.746	0.746			6.887	0.190	
				0.573	1.91			1.765
1-02-40	13.577	5.205	1.319			7.053	0.193	
				0.623	2.08			2.126
1-03-10	14.775	5.664	1.942			7.169	0.197	
				0.698	2.33			2.476
1-03-40	15.975	6.123	2.640			7.212	0.198	
				0.761	2.54			3.082
1-04-10	17.171	6.582	3.401			7.188	0.198	
				0.812	2.71			3.074
1-04-40	18.369	7.041	4.213			7.115	0.196	
				0.861	2.87			4.424
1-05-10	19.567	7.500	5.074			6.993	0.193	
				0.878	2.93			4.003
1-05-40	20.765	7.959	5.952			6.854	0.189	
				0.864	2.88			3.621
1-06-10	21.963	8.418	6.816			6.729	0.185	
				0.873	2.91			3.505
1-06-40	23.161	8.877	7.689			6.595	0.182	
				0.861	2.87			3.650
1-07-10	24.359	9.356	8.550			6.473	0.178	
				0.917	3.06			3.815
1-07-40	25.557	9.795	9.467			6.295	0.173	
				0.898	2.96			3.674
1-08-10	26.755	10.254	10.365			6.136	0.169	
				0.914	3.05			3.715
1-08-40	27.953	10.713	11.279			5.961	0.164	
				0.924	3.08			3.575
1-09-10	29.151	11.172	12.203			5.776	0.159	
				0.936	3.12			3.727
1-09-40	30.349	11.631	13.139			5.579	0.154	
				0.931	3.10			3.746
1-10-10	31.547	12.090	14.070			5.387	0.148	
				0.950	3.17			3.834
1-10-40	32.745	12.549	15.020			5.176	0.143	
				0.943	3.14			3.709
1-11-10	33.943	13.008	15.963			4.972	0.137	

Plot No. 7 Slope 9.3% Date 8/17/38 Run No. 31 Intensity 3.96" Duration 15 min.

Plot Moisture 0-6" 15.9, 6-12" 18.8, 12-18" 18.5 Vol. Wt. Upper 6" 1.23, Lower 6" 1.55 Sheet No. 2 of 2 sheets

Dry Run

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft.	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
				0.941	3.14			3.552
1-11-40	35.141	13.467	16.904			4.770	0.131	
				0.619	3.09			2.267
1-12-00	35.937	13.773	17.523			4.641	0.128	
				0.309	3.09			1.133
1-12-10		13.926	17.832			4.179	0.115	
				0.594	1.98			1.654
1-12-40		14.385	18.426			3.126	0.086	
				0.271	0.91			0.408
1-13-10		14.844	18.700			2.393	0.066	
				0.114	0.38			0.086
1-13-40		15.303	18.814			1.820	0.050	
				0.029	0.10			0.012
1-14-10		15.762	18.843			1.332	0.037	
				0.011	0.04			0.000
1-14-40		16.221	18.854			0.862	0.024	
				0.003	0.01			0.000
1-15-10		16.680	18.857			0.400	0.011	
				0.002	0.01			0.000
1-15-40		17.057	18,880			0.000	0.000	
TOTALS	35.937	17.057	18.880					72.644

Net percentage runoff 52.3%

Soil loss by end point determination 70.64 pounds

Density of runoff 3.727 lbs. per cu. ft.

Infiltration rate 1.510 in. per hour

Plot No. 7 Slope 9.3% Date 8/17/38 Run No.32 Intensity 3.96" Duration 15 min.

Plot Moisture 0-6" 18.32, 6-12" 18.57, 12-18" 16.82 Vol. Wt. Upper 6" 1.23, Lower 6" 1.55 Sheet No. 1 of 2 sheets

Wet Run

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
2-26-00	0.000	0.000						
	1.597	0.236						
2-26-40	1.597	0.236	0.000			1.361	0.037	
	1.198	0.177		0.131	0.44			0.263
2-27-10	2.795	0.413	0.131			2.251	0.062	
				0.474	1.58			1.202
2-27-40	3.993	0.590	0.605			2.798	0.077	
				0.854	2.85			2.957
2-28-10	5.191	0.767	1.459			2.965	0.082	
				1.024	3.41			3.928
2-28-40	6.389	0.944	2.483			2.962	0.082	
				1.005	3.35			3.884
2-29-10	7.587	1.121	3.488			2.978	0.082	
				1.019	3.40			3.785
2-29-40	8.785	1.298	4.507			2.980	0.082	
				1.049	3.50			4.273
2-30-10	9.983	1.475	5.556			2.952	0.081	
				0.956	3.19			2.959
2-30-40	11.181	1.652	6.512			3.017	0.083	
				0.973	3.24			4.088
2-31-10	12.379	1.829	7.485			3.065	0.084	
				1.003	3.34			4.229
2-31-40	13.577	2.006	8.488			3.083	0.085	
				0.977	3.26			4.099
2-32-10	14.775	2.183	9.465			3.127	0.086	
				1.023	3.41			4.522
2-32-40	15.973	2.360	10.488			3.125	0.086	
				1.042	3.47			4.908
2-33-10	17.171	2.537	11.530			3.104	0.086	
				1.019	3.40			4.732
2-33-40	18.369	2.714	12.549			3.106	0.086	
				1.039	3.46			5.212
2-34-10	19.567	2.891	13.588			3.088	0.085	
				1.029	3.43			4.822
2-34-40	20.765	3.068	14.617			3.080	0.085	
				1.011	3.37			4.798
2-35-10	21.963	3.245	15.628			3.090	0.085	
				0.985	3.28			4.963
2-35-40	23.161	3.422	16.613			3.126	0.086	
				1.009	3.36			5.128
2-36-10	24.359	3.599	17.622			3.138	0.086	
				1.084	3.61			6.265
2-36-40	25.557	3.776	18.706			3.075	0.085	
				1.001	3.34			5.671
2-37-10	26.755	3.953	19.707			3.095	0.085	

Plot No. 7 Slope 9.3% Date 8/17/38 Run No. 32 Intensity 3.96" Duration 15 min.

Plot Moisture 0-6" 18.32, 6-12" 18.57, 12-18" 16.82 Vol. Wt. Upper 6" 1.23, Lower 6" 1.55 Wet Run Sheet No. 2 of 2 sheets

Time	Cumul've Rainfall Cu.Ft.	Cumul've Infil'n Cu.Ft.	Cumul've Runoff Cu.Ft.	Runoff Inc'm'ts Cu.Ft.	Runoff In.perHr	Surface Deten'n Cu.Ft.	Surface Deten'n Inches	Soil Loss Inc'm'ts Pounds
				1.028	3.43			5.722
2-37-40	27.953	4.130	20.735			3.088	0.085	
				1.074	3.58			6.156
2-38-10	29.151	4.307	21.809			3.035	0.084	
				1.037	3.46			5.630
2-38-40	30.349	4.484	22.846			3.019	0.083	
				0.984	3.28			5.088
2-39-10	31.547	4.661	23.830			3.056	0.084	
				0.979	3.26			5.081
2-39-40	32.745	4.838	24.809			3.098	0.085	
				0.997	3.32			5.100
2-40-10	33.943	5.015	25.806			3.122	0.086	
				1.027	3.42			5.141
2-40-40	35.141	5.192	26.838			3.116	0.086	
				0.723	3.61			3.913
2-41-00	35.937	5.310	27.556			3.071	0.085	
				0.361	3.61			1.956
2-41-10		5.369	27.917			2.651	0.073	
				0.697	2.32			2.765
2-41-40		5.546	28.614			1.777	0.049	
				0.338	1.13			0.854
2-42-10		5.723	28.952			1.262	0.035	
				0.154	0.51			0.182
2-42-40		5.900	29.106			0.931	0.026	
				0.052	0.17			0.029
2-43-10		6.077	29.158			0.702	0.019	
				0.030	0.10			0.013
2-43-40		6.254	29.188			0.495	0.014	
				0.008	0.03			0.000
2-44-10		6.431	29.196			0.310	0.009	
				0.001	0.003			0.000
2-44-40		6.608	29.197			0.132	0.001	
				0.001	0.003			0.000
2-45-00		6.728	29.209			0.000	0.000	
TOTALS	35.937	6.728	29.209					134.318

Net percentage runoff 81.2%

Soil loss by end point determination 132.67 pounds

Density of runoff 4.55 lbs. per cu.ft.

Infiltration rate 0.588 in. per hour

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